PROFILE MEASUREMENTS OF PORTLAND CEMENT CONCRETE TEST SLAB AT THE NATIONAL AIRPORT PAVEMENT TEST FACILITY

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INTRODUCTION

A portland cement concrete (PCC) test slab was constructed at the Federal Aviation Administration's (FAA) National Airport Pavement Test Facility (NAPTF) for the purpose of verifying a particular mix design. The test slab measured 15′ × 15′ (4.6 m × 4.6 m) and was constructed over an existing cracked 20′ × 20′ (6.1 m × 6.1 m) slab. The test slab was placed on Kraft brown paper bond breaker and was instrumented with strain gauges, clip gauges, vertical and horizontal displacement transducers, and temperature and relative humidity sensors. Personnel from the FAA's Airport Technology Research & Development Branch utilized the opportunity to collect response data of the corner curling during the early life phase of the concrete test slab. Using an FAA pavement surface profiling device, data was collected during a 3 month period, commencing at placement of the concrete. This report describes the FAA profiling equipment, the data collection process, the analysis of the response data measured by the profiling device and the comparison of the slab curling measurements obtained with the profiling device, and the in situ vertical displacement transducers installed in the slab.

PROFILE MEASUREMENT EQUIPMENT

The FAA inertial profiling device was initially assembled to measure the surface elevation profiles of airport pavements as described in reference [1]. The FAA has adapted this profiling device to measure the transverse absolute elevation profile of the traffic lanes at the NAPTF.

The current configuration of the FAA pavement surface profiling device consists of a vertical displacement transducer, an incremental rotary encoder, a data acquisition box, and a laptop personal computer. The profiling equipment is mounted on a trolley that rolls along the flange of an aluminum beam 24 ft (7.3 m) long, as shown in Figures 1 and 2. The beam has a steel top member for reinforcement and stability.

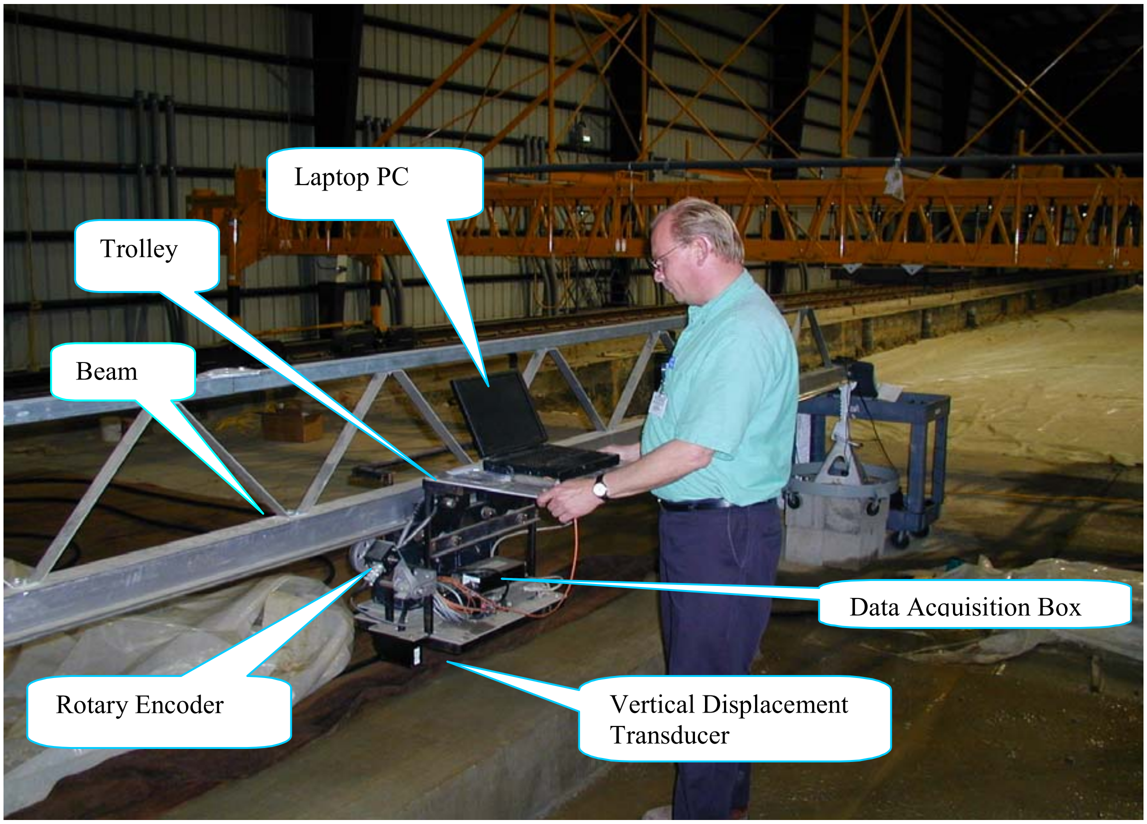
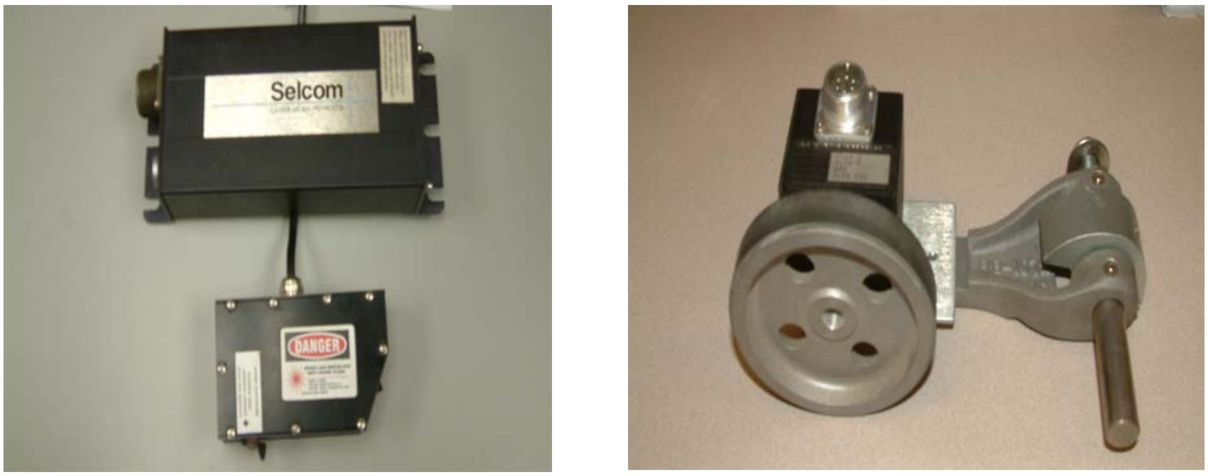


Figure 1. FAA pavement profiling equipment configured for measurements of test slab.

Figure 2. FAA pavement profiling device at NAPTF.

The vertical displacement transducer is a Selcom (Figure 3a) infrared laser unit with a spot size of 0.04 inch (1 mm). The unit is located approximately 6 inches (15.2 cm) from the PCC test slab surface and used to measure absolute elevation profile of the slab surface.

The incremental rotary encoder (Figure 3b) is used to measure the distance on which the profiling device travels along the beam. The resolution of the distance measurement is 0.02 inch.



(a) (b)

Figure 3. Individual components of the FAA’s pavement surface profiling device.

The data acquisition box accepts data from the infrared laser unit, along with the pulse train from the encoder. The laser unit samples at a 32 kHz rate but the data is stored at a 8 kHz rate.

The laptop PC is used to collect and store the measurement data when the profiling device is running.

TEST ITEM DESCRIPTION

The PCC test slab measured 15′ ×15′ (4.6 m × 4.6 m) and was constructed over an existing cracked 20′ × 20′ (6.1 m × 6.1 m) slab. The slab was placed on Kraft brown paper bond breaker.

The PCC test slab was instrumented with concrete strain gauges (CSG), clip gauges (CL), vertical displacement transducers (VD), relative humidity sensors (RH), and a temperature tree (T).

The sensors monitored the slab responses during its whole life including watering in the first 28 days, drying about 4 months, watering again for one and half months, and drying again for 1 month. However, profile data was only collected during the first 3 months. Figure 4 displays the locations of all the vertical displacement transducers and the profile measurement line.

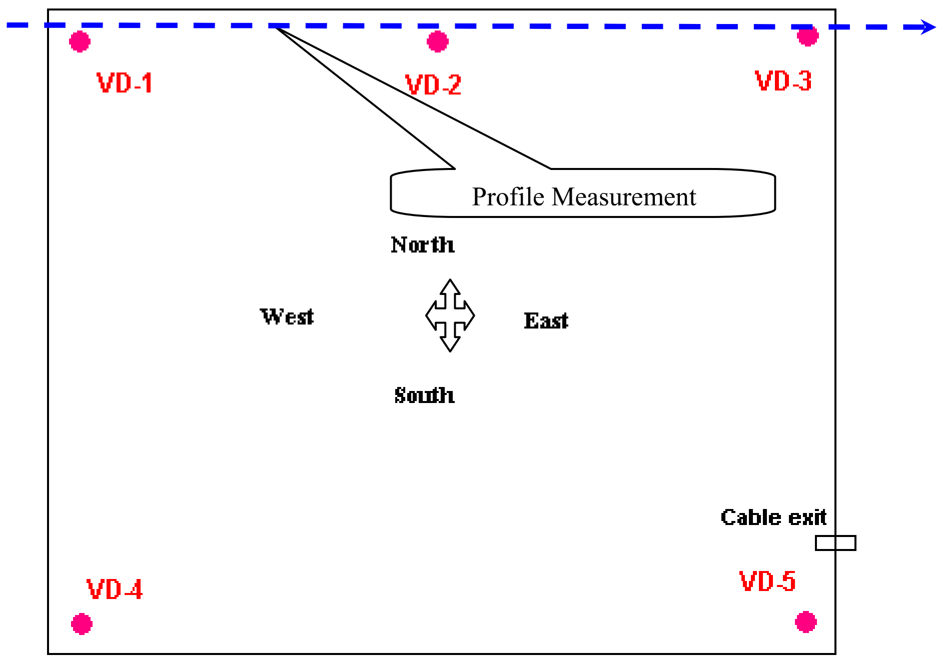


Figure 4. Locations of vertical displacement transducers and profile measurement.

PROFILE MEASUREMENT

The FAA profiling device was used to measure the profile of the test slab surface during a 3 month period, commencing directly after placement of the concrete. The device was driven along the north edge of slab from the west to east (Figure 4) twice a day (morning and afternoon). Each measurement is repeated three times. The data collected from the device is saved as a binery file by the name of date and time.

The FAA has developed its own software, in Visual Basic, called ProFAA, for use in analyzing the profile data. An adopted version of this software called "ReadSelTransverse" is used to match the latest profiling device configuration to make a comparison of all the profiles collected.

Figure 5 shows personnel collecting the profile data with the FAA pavement surface profiling device. Note the early age of the test slab by the forms not yet removed. The test slab was kept wet during the early age (the 28 day curing process) by covering the test slab and soaking the burlap.

Figure 5. Data collection with FAA pavement surface profiling device.

Figure 6 plots some of the profiles measured from 6/2/2003 to 9/4/2003. These profiles have been normalized to set zero at the profile ends for a reference point. They have also been filtered to smooth out small scale surface irregularities. Figure 6 clearly shows the changes of the profiles along the north edge of the slab in the first 3 months.

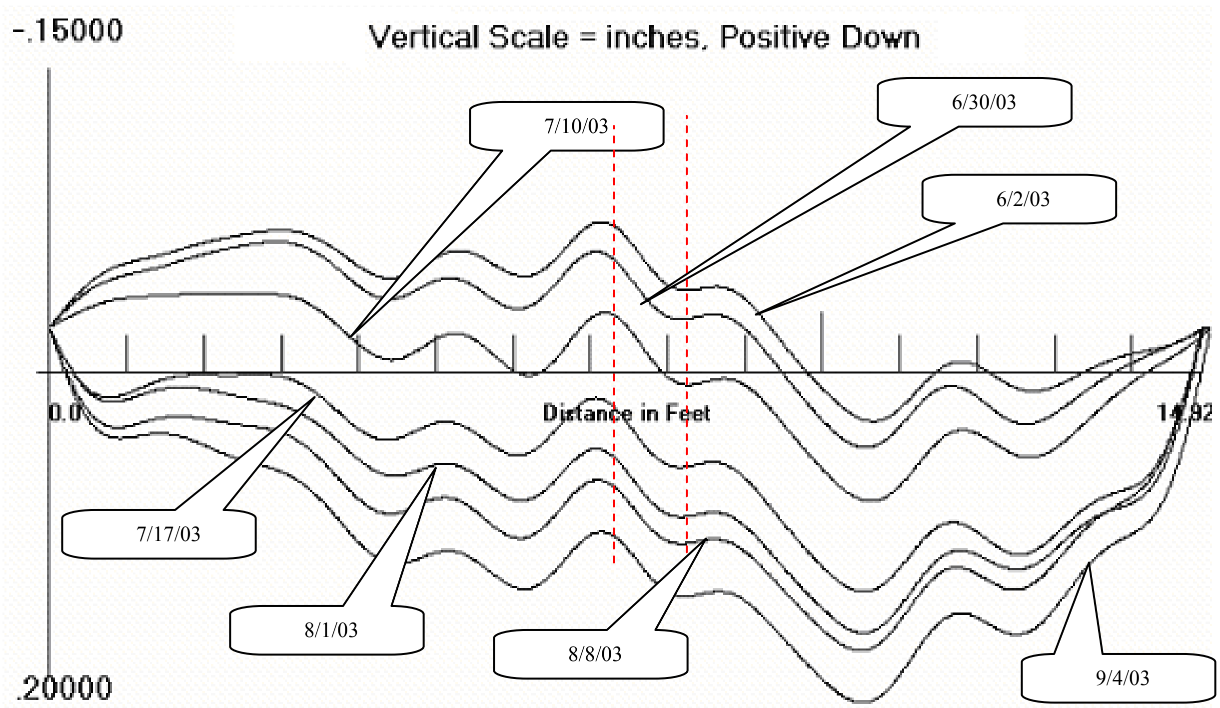


Figure 6. Selected profiles along North edge of test slab from 6/2/2003 to 9/4/2003.

Figure 7 shows the changes of displacements at the north-west corner (VD1) and the center of the north edge (VD2) from the in situ VD sensor . In Figure 7, the upward displacement is negative and first reading is set as zero.

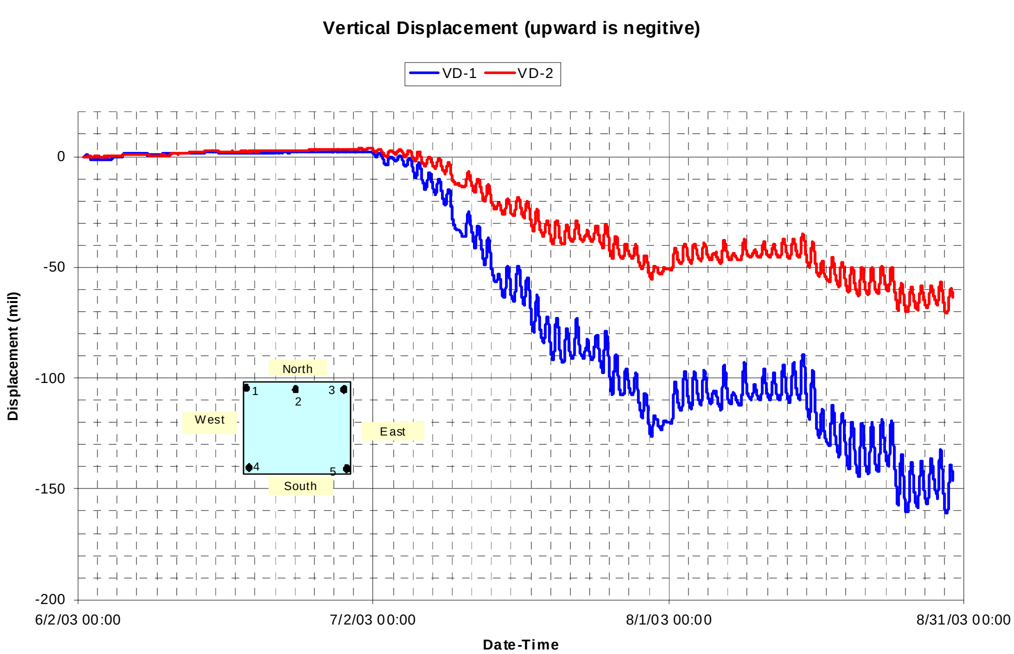


Figure 7. Displacements at the north-west corner (VD1) and the center of north edge.

The test slab was covered with burlap and plastic film and subjected to a watering cycle during the first month. The completely wet curing method kept the slab almost flat within that period. However, after watering was stopped, and the burlap and plastic removed, the slab dried gradually. The curling at the corner of the slab and along the slab edge developed gradually. The corner curling is always higher than along any one edge, as shown in Figure 7. With the curling continually developing, the profile shapes continue to become more concave, as shown in Figure 6, from 7/17/2003 to 9/4/2003.

The following factors had an influence on the profile measurements:

- The beginning and end positions of the collected profiling data are marked to keep the same measurement location during the test slab life cycle.
- The speed of the trolley device is kept as constant as possible.
- The profile support beam was calibrated in May 2003. However during the profiling period, the environmental changes (temperature, relative humidity…) caused deflection of the beam support to vary the profile offset. This will be corrected in future measurements.

Figure 8 shows the displacement at the center of the profile measurements versus temperature during June 2003 when the slab was wet. The pavement level air temperature varied from 60o to 80oF. The range of displacement changes were about 50 mils. However, Figure 7 shows that the wet slab was almost flat in June 2003. Hence, the displacement changes probably were caused by curling of the beam due to the use of a steel top member above the aluminum I-beam. The steel top member will be replaced in the future by an aluminum part to reduce errors due to warping of the beam induced by temperature variations.

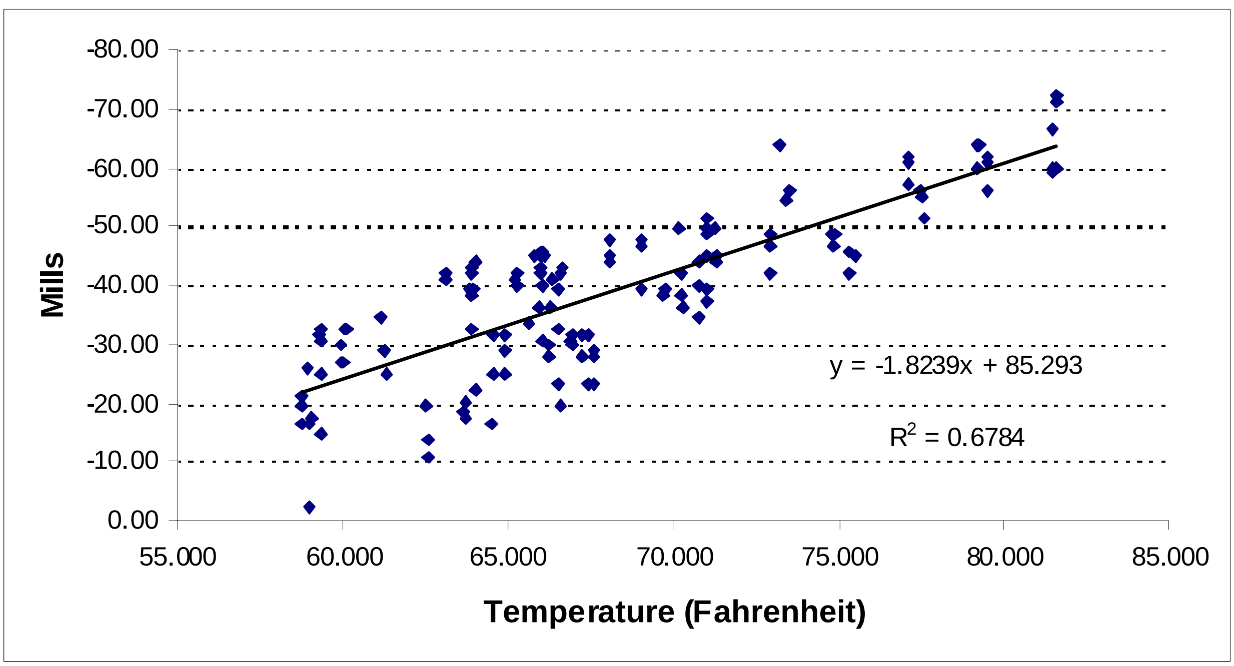


Figure 8. Displacement at the Center of Profiles vs. Temperature.

COMPARISON OF DATA COLLECTED WITH THE PROFILLING DEVICE AND THE IN-SITU VERTICAL DISPLACEMENT TRANSDUCERS

The in situ vertical displacement gages (VDs) are used to measure the vertical deflections of the slab. Gage VD2 is located at the center of north edge of the slab. The other four gages (VD1, VD3, VD4, and VD5) are positioned at the corners of the slab (i.e., Figure 4). The FAA profiling device was used to measure the profile along the north edge of the slab from the west to east. The locations of VD1,VD2, and VD3 are very close to the path of the profiling device. For comparing the profiling device measurements with the in situ Vertical Dislpacement Transducers, we define an index:

Rc = The reading at the center of profile with zero at the profile ends, as shown in Figure 9.

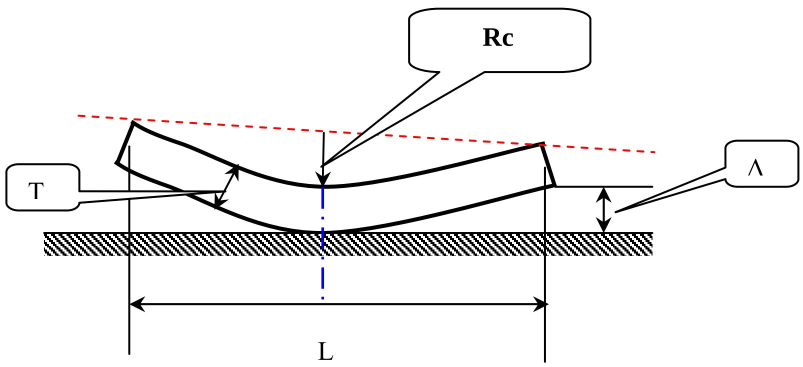


Figure 9. Idealized View of a Curled Slab.

Rc is compared with the difference between the average of the corner deflections and the center deflection on the north edges of the slab 0.5 *(V3+V1)-V2. Note that sensor VD3 did not work past 6/16/03, therefore, 0.5*(V3+V1) is replaced by the average of the corner deflections of the slab, (V1+V4+V5)/3 or V3=V1 is assumed. Figure 10 shows the time histories of the Rc and VD measurements with initial values = 0. Figure 11 gives the relationship between the readings of VD2 and the corner deflections of the slab. They show a strong linear relation. Rc, is therefore, a good indication of curling of the slab corners with, in this case, a proportionality factor of slightly more than two.

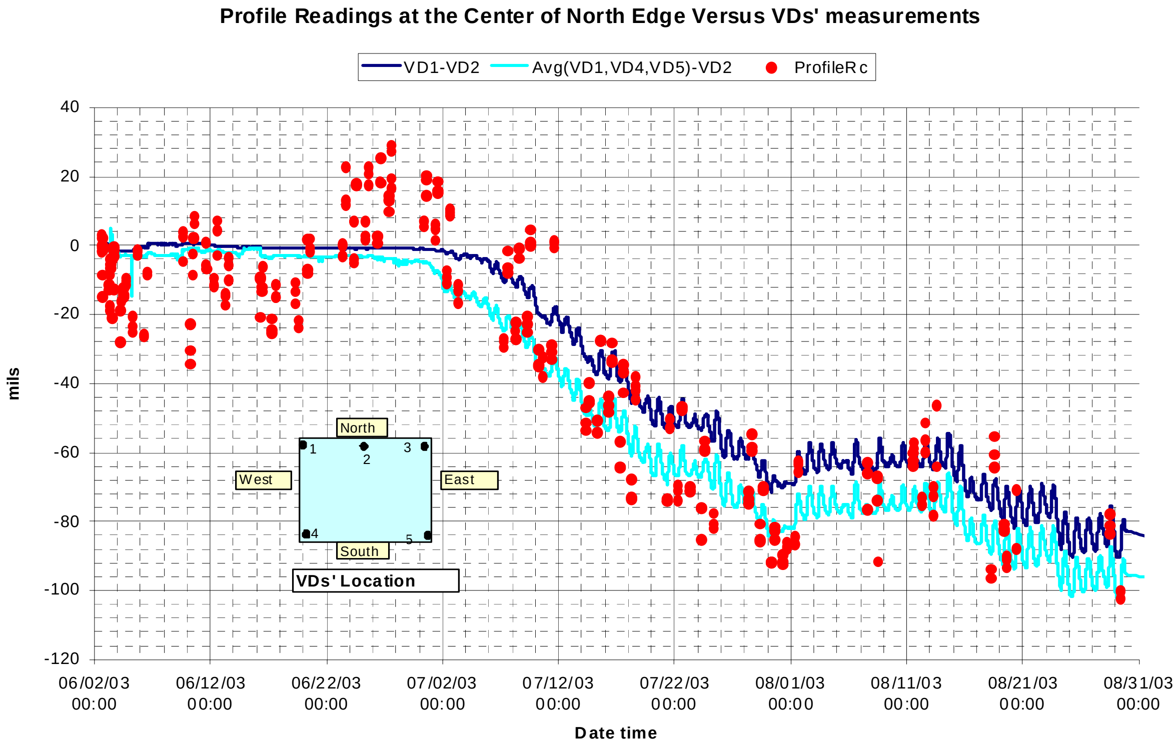


Figure 10. Relationship of deflections at center of north edge vs. vertical displacement transducers.

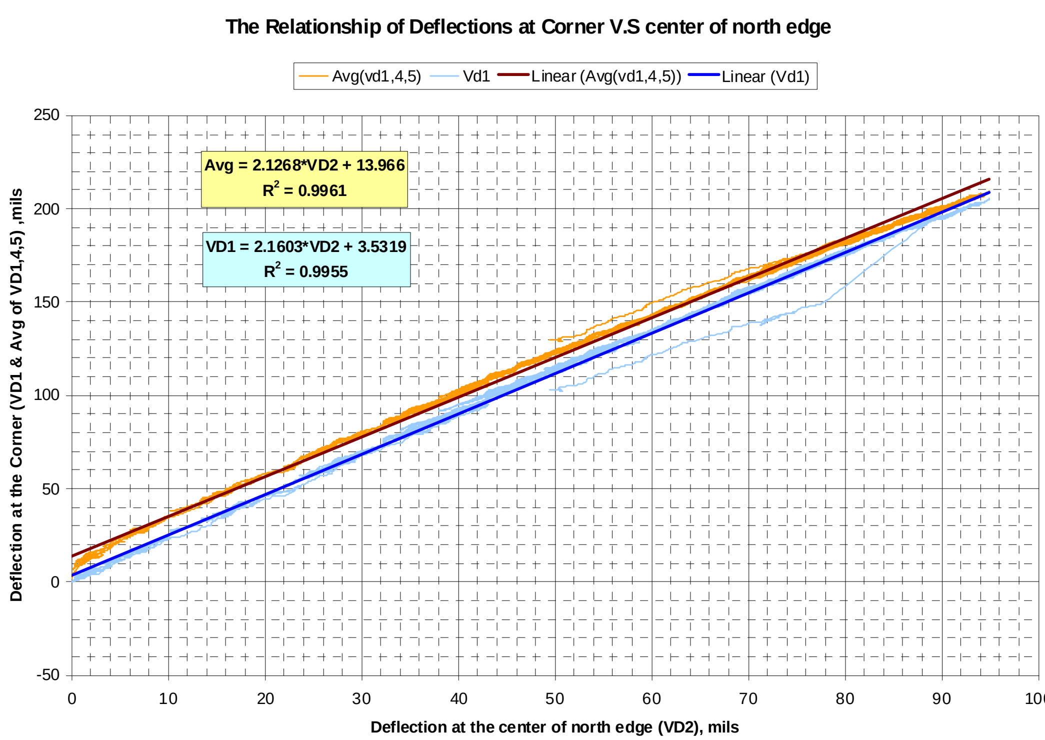


Figure 11. Relationship of deflections at the corners versus at the center of slab edge.

The estimating method used was as follows:

1. Measure the profile along the slab edge.
2. Take Rc from the profile.
3. Assume the slab corner curling Vsc = α * Rc in which the user can select α. As an example, reference [2] provides a simple formula for evaluating the slab curling:

$$\Delta = \frac{S_c * L^2}{8 * T} \tag{1}$$

Where (see Figure 9):
Δ = Upward curling of slab
S_c = Difference in lineal unit shrinkage between top and bottom of slab
L = Length of slab (Use diagonal length to get corner curling)
T = Slab thickness (Assumed un-reinforced)

The diagonal length of an L x L slab is equal to $\sqrt{2} * L$. Assume S_c is constant; the corner curling of the slab is twice the curling at the edge center. Therefore, α = 2, which is close to the results in Figure 11.

Figure 12 shows the slab curling measurements and the results from the estimated method with α = 2. It is evident that the estimated results closely approximate the true vertical deflection at the corners. However, the slab edges were not constrained and the relationship will not necessarily hold when adjacent slabs constrain each other by aggregate interlock or by dowel or tie bar reaction.

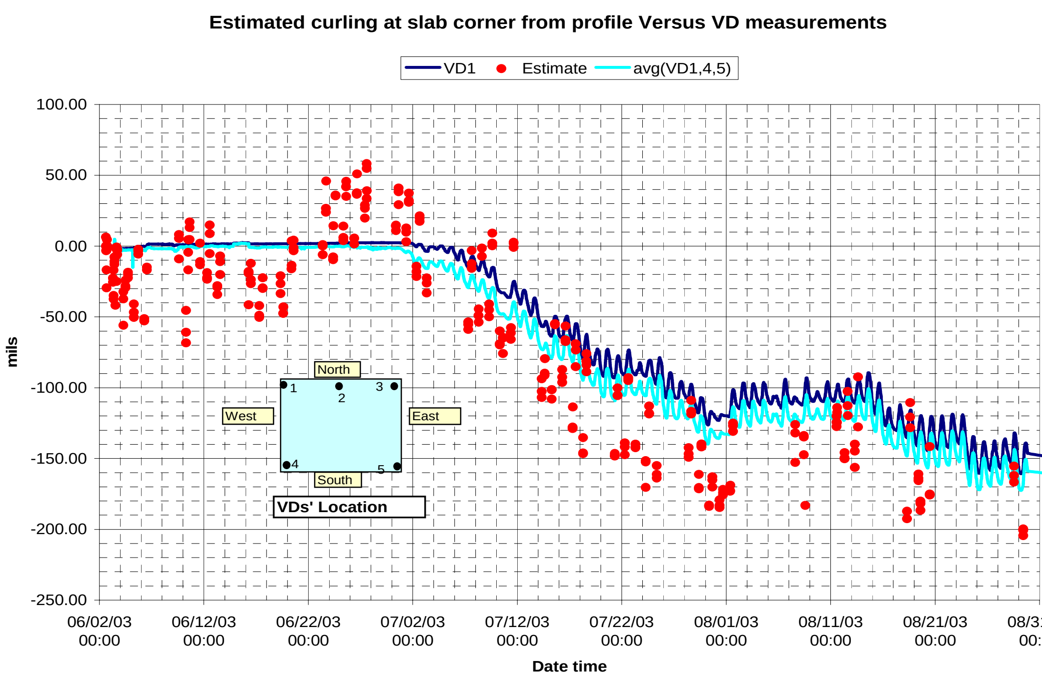


Figure 12. Comparison of the slab curling measurements with the estimated curling.

SUMMARY

1. The FAA pavement surface profiling device is reliable and easily used. Its measurements are repeatable.

2. The measurements of in situ vertical displacement sensors demonstrate the reasonableness of the profile measurements of the PCC test slab.

3. The test slab was almost flat within the first watering period. After watering was stopped, the slab dried gradually. The curling at the corner of the test slab and along the slab edge was developed gradually, and the profile shapes concaved more and more.

4. The measurements of the FAA pavement surface profiling device offer not only the profile of a slab, but a way of estimating slab curling.

ACKNOWLEDGMENTS/DISCLAIMER

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